UNIVERSITY OF SWAZILAND
FACULTY OF SCIENCE

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
MAIN EXAMINATION DECEMBER 2009

TITLE OF PAPER : **ANTENNAS AND WAVE PROPAGATION**

COURSE NUMBER : **EC0510**

TIME ALLOWED : **THREE HOURS**

INSTRUCTIONS : **READ EACH QUESTION CAREFULLY ANSWER ANY FOUR OUT OF FIVE QUESTIONS. EACH QUESTION CARRIES 25 MARKS. MARKS FOR EACH SECTION ARE SHOWN ON THE RIGHT-HAND MARGIN.**

THIS PAPER HAS 8 PAGES INCLUDING THIS PAGE.

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USEFUL INFORMATION

R_r - radiation resistance $$R_r = 790\left(\frac{\ell}{\lambda}\right)^2$$

The effective relative permittivity of a dielectric $$\epsilon = 1 - \frac{e^2 N}{m\omega^2 \varepsilon_0}$$

Electronic charge $e = 1.6 \times 10^{-19}$ C

Permittivity of space $\varepsilon_0 = 8.85 \times 10^{-19}\ F/m$

Electronic mass $m = 9 \times 10^{-31}$ kg.

Effective radius of the earth plus the mean terrain level $R_e = 8500$ km

Antenna efficiency factor $k = 0.55$

Gain for $\lambda/2$ dipole antenna 1.64

General expression for gain $(4\pi k)$ (effective area) / λ^2

The radar equation $$P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 r^4}$$

Figure of merit for a $\lambda/2$ dipole antenna 222

QUESTION 1

(a)

(i) Explain radiation resistance as applied to antennae.

(2 marks)

(ii) Consider a non-synchronized medium frequency radio transmitter which is operating at the same frequency as that of the wanted signal transmitter, but broadcasting a different program from 10:00 am to 10:00 pm. Will there be interference ? Explain.

(2 marks)

(b) (i) Compute the range of good reception from an AM radio broadcasting transmitter with E_1 = 1500 mV/m over a ground path with mean conductivity σ = 10 mS/m. Take the minimum level for good reception as 10 mV/m in a town, given the numerical distance of 2.0.

(9 marks)

(ii) One distinguishing characteristic of the ionized layers of the ionosphere is the difference in electron densities, ***N*** (the number of free electrons per cubic meter).
Define the refractive index *n* of the ionosphere and deduce a simple expression for ***n*** in terms of ***N*** and frequency of propagation ***f***.

(8 marks)

(iii) It is desired to use an ionized region of the atmosphere exhibiting an electron density of $2 \times 10^{12}\ m^{-3}$ to reflect vertically launched signals propagating at 11 MHz. back to earth. Will this be possible under the given conditions? Show your calculations.

(4 marks)

QUESTION 2

(a) A 1 MHz transmitter with $\mathbf{E_1}$ = 3000 mV m^{-1} is used for communication with a receiver situated 300 km away. The ground path consists of 100 km of ground with parameters σ = 10 mS m^{-1} and ϵ_r = 4, followed by a further 200 km of sea with parameters σ = 4000 mS m^{-1} and ϵ_r = 80. With reference to Figure 2, compute the predicted electric field strength at the receiver.

(15 marks)

(b) Two or more similar antenna elements can be used to obtain better directivity and directional gain. The radiation pattern of a single horizontally polarized half - wavelength dipole antenna is bidirectional. This can be greatly improved to give a radiation pattern where most of the energy is concentrated towards one direction only. Explain, using diagrams where necessary, a simple inexpensive way of achieving this using a second half - wavelength dipole antenna.

(10 marks)

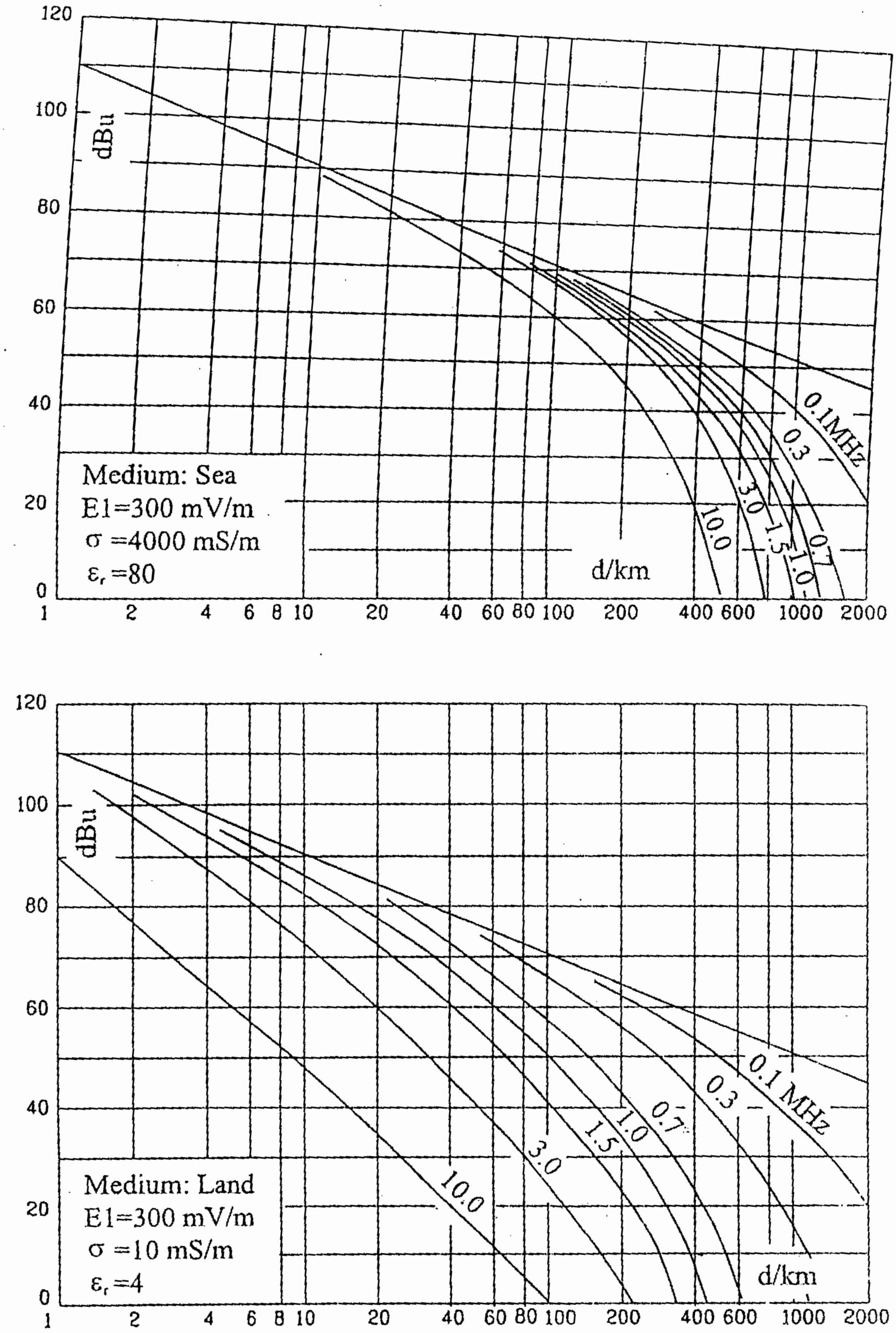
dBu
Medium: Sea
E1=300 mV/m
σ =4000 mS/m
ε_r =80
d/km
0.1MHz
0.3
0.7
1.0
1.5
3.0
10.0
0
20
40
60
80
100
120
1
2
4
6
8
10
20
40
60
80
100
200
400
600
1000
2000
dBu
Medium: Land
E1=300 mV/m
σ =10 mS/m
ε_r =4
d/km
0.1 MHz
0.3
0.7
1.0
1.5
3.0
10.0

Figure 2

QUESTION 3

(a) An electromagnetic wave of field strength $E = E_o Sin(\omega t)$ is incident on an ionized medium with *N* free electrons per m^3 available for conduction. Taking the total force on the electron to include that due to collisions between gas molecules and electrons, and neglecting the effect of the earth's magnetic field, derive the following:

(i) Expressions for both the conductivity σ and the relative permittivity ϵ_r of the medium if the total current density can be expressed as $J = \sigma E + j\omega\varepsilon E$, where ε is the permittivity of the material.

(7 marks)

(ii) An expression for the critical frequency for the medium using results of (i) above.

(3 marks)

(b) A 100 m high transmitting antenna is located 60 km from a receiver. Calculate the required height of the receiving antenna which will enable line - of - sight reception.

(6 marks)

(c) What is an array ? Give two main advantages offered by the use of arrays over the use of a single antenna with reference to radiation of electromagnetic waves.

(3 marks)

(d) A λ/2 dipole antenna operating at 300 kHz is supplied with 1 mA rms current, what is the unattenuated field at 1 km from the antenna?

(6 marks)

QUESTION 4

(a) A radar system consists of a transmit and receive antenna at distances of $\mathbf{r_t}$ and $\mathbf{r_r}$ respectively from a target object. Both antennas are pointed such that the pattern maxima are directed toward the target which has an echoing area **δ**.

If the power reaching the target is isotropically scattered, derive an expression for the power scattered by the target which reaches the receiver, as a function of the echoing area, **δ**.

(5 marks)

(b) A 9 GHz radar is tracking a target of 0.02 m^2 echoing area at a range of 100 km. The gain of the common transmitting and receiving antenna is 45 dB. A high power transmitter delivering 1 MW of power is used with a low noise receiving system having a noise bandwidth of 1 MHz and T = 60 K.

Determine

(i) the received signal power in dBm, and (6 marks)

(ii) the received signal - to - noise ratio in dB. (5 marks)

(c) (i) How far will the radio horizon be from a horizontally polarized antenna placed on a 400 m high tower?

(3 marks)

(ii) A receiving antenna is placed 100 km from the horizontally polarized one.

How high should it be raised to receive a good direct signal ?

(4 marks)

(iii) Explain what is meant by the term effective aperture as applied to antennae.

(2 marks)

QUESTION 5

(a) The power density of an isotropic radiator, fed with power ***P*** watts is measured at distance **r** away. Derive expressions for the magnitudes of both the electric and magnetic field intensities at ***r*** from the radiator.

(7 marks)

(b) The point source of (a) is replaced by a transmitting antenna of power gain 20 dB in the direction of maximum radiation and radiation resistance of 50 Ω. A receiver is placed at r = 50 km from the transmitter. For an excitation current of 0.5 A in the transmitting antenna, determine

(i) the power density , (5 marks)

(ii) the electric field intensity at the receiver, (3 marks)

(iii) Its effective length if the induced voltage in the receiving antenna is 4 mV and its radiation resistance is 73 Ω.

(3 marks)

(iv) Determine the total power available to a receiver under matched conditions. (3 marks)

(c) An antenna of impedance $\mathbf{Z_{in}}$ is connected to a receiver with the input terminated in a resistor $\mathbf{R_i}$. If **V** is the effective value of the induced voltage in the antenna, derive an expression for maximum power transfer to the receiver.

(4 marks)